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EVALUATION OF CORROSION INHIBITOR ADDITIVES FOR ALKALINE FLIGHT--ETC(U)

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U. S. NAVAL AIR ENGINEERING CENTER

LAKEHURST, NEW JERSEY

NAEC-ENG-7930 23 Nov 1977

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DEPARTMENT OF THE NAVY ★ NAVAL AIR ENGINEERING CENTER ★

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PREPARED BY George A. Gehring Jr.
George A. Gehring, Jr.
Doreen L. Behmke
Doreen L. Behmke

APPROVED BY George V. D. Bease

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The flight deck cleaning detergent specified by NAVSHIPS Bulletin is a highly alkaline, 3% sodium metasilicate solution. It was found to accelerate corrosion of the aluminum track covers on the USS Roosevelt.

Laboratory tests showed that sodium naphthenate at a → over

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proper concentration inhibits corrosion of aluminum in alkaline solutions. However, sodium naphthenate degrades the cleansing ability of the metasilicate/detergent solution on cetain soiling mediums. Thus, it does not appear feasible to use sodium naphthenate as an additive in deck cleaning solutions.

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I. INTRODUCTION

The flight deck cleaning detergent specified by NAVSHIPS Bulletin is a highly alkaline, 3% sodium metasilicate solution. It was found to accelerate corrosion of the aluminum track covers on the USS Roosevelt. The alternate solution specified is a jet fuel-detergent mixture and is used with reluctance.

The high alkalinity not only provides the sodium metasilicate detergent with its cleansing properties, but unfortunately is the root of the corrosion problem.

Accordingly, NAVAIRENGCEN instituted a program to identify corrosion inhibitor additives and evaluate the effect of the most promising additive on the corrosivity and cleanability of the detergent.

II. SUMMARY

Laboratory tests showed that sodium naphthenate at a proper concentration inhibits corrosion of aluminum in alkaline solutions. However, sodium naphthenate degrades the cleansing ability of the metasilicate/detergent solution on certain soiling mediums. Thus, it does not appear feasible to use sodium naphthenate as an additive in deck cleaning solutions. There might be other inhibitor additives that can also reduce alkaline corrosion and yet not degrade the solution cleansing ability. However, a better approach now appears to be to find a substitute cleaning solution.

The use of aluminum-coated steel and aluminum alloy components is increasing on aircraft carriers. The Navy must resolve the alkaline cleaner corrosion problem to avoid further corrosion failures. Resolution of the problem requires finding, testing and evaluating an inhibitor additive for the current cleaning solution or a substitute cleaning solution which is compatible with present hardware on U.S. Navy aircraft carriers.

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V. EVALUATION OF CORROSION INHIBITOR ADDITIVES FOR ALKALINE FLIGHT DECK CLEANING SOLUTIONS

A. INTRODUCTION

NAVSHIPSNOTE 9140, Service Bulletin 6634A-363 dated June 2, 1966 specifies a highly alkaline 3% sodium metasilicate/≈3% water soluble detergent (MIL-D-16791E, Type I) solution for cleaning aricraft carrier flight decks especially around the catapult tracks. Use of this highly alkaline solution (pH≈13) is believed to be the primary cause of accelerated corrosion of aluminum-coated catapult track covers onboard the USS Roosevelt. The use of alkaline solutions to clean aircraft on the flight deck might also have contributed to the problem. While the above-referenced bulletin specifies thorough rinsing of the cleaning solution after washing, the rinsing procedure is inadequate to control corrosion of aluminum by the sodium metasilicate detergent.

The alternate solution specified for deck cleaning in NAVSHIPSNOTE 9140 combines JP-5 jet fuel with an oil-soluble detergent. Because of environmental concern, the fleet is reluctant to use the jet fuel to clean the decks and is using primarily the sodium metasilicate/water-soluble detergent solution or highly alkaline commercial cleaning solutions. Widespread use of the alkaline cleaning solutions threatens other aluminum-coated hardware and aluminum alloy components (e.g., Jet Blast Deflectors) in the flight deck area.

The metasilicate/detergent solution derives its excellent cleansing properties from its high active alkalinity caused by addition of the metasilicate. However, it is the same high alkalinity which creates corrosion problems for aluminum components. The use of a chemical with a lower active alkalinity such as sodium carbonate (pH ≈ 11.5) would probably reduce the corrosion problem, but at the same time it would reduce the cleansing power.

Accordingly, NAVAIRENGCEN initiated a 2-phase program to evaluate corrosion inhibitor additives for the alkaline cleaning solution. The first phase identified candidate inhibitor additives and screened their ability to reduce corrosion of metallized aluminum. The second phase investigated the effect of the most promising inhibitor (sodium naphthenate) on the cleanability of the alkaline cleaning solution. This report presents the results of the program.

B. EXPERIMENTAL APPROACH

1. PHASE I - IDENTIFY AND SCREEN CANDIDATE CORROSION INHIBITORS

A literature review identified several chemical compounds (Table I) that might be used as corrosion inhibitors in caustic solutions. Previous work by Kyazimov[1] suggested that sodium naphthenate would be most effective from a performance and cost standpoint. Sodium naphthenate is synthesized from naphthenic acid derived from crude oil.

Laboratory tests evaluated the effectiveness of sodium naphthenate in reducing the corrosivity of alkaline solutions to aluminum. The tests investigated corrosion of aluminum as a function of:

a. % sodium metasilicate

b. % sodium naphthenate

c. pH

d. Time

A metallized aluminum test specimen (≈1" x 1" x ¼") was prepared by flame-spraying aluminum into a sand mold and subsequently stripping the mold. Prior to exposure, the test specimen was cleaned, degreased in acetone, and air dried. The test specimen was allowed to stabilize in each test solution for a period of 24 hours. After 24 hours, a linear polarization measurement* determined the corrosion rate of the aluminum specimen.

The laboratory tests also investigated the effectiveness of the sodium naphthenate over an extended period (170 hrs.). Linear polarization measurements at different times during the 170 hr. test determined corrosion rate as a function of time.

2. PHASE II - INVESTIGATE THE EFFECT OF SODIUM NAPHTHENATE ON THE CLEANSING ABILITY OF A 3% SODIUM METASILICATE DETERGENT SOLUTION.

This phase of the program investigated the cleansing ability of sodium metasilicate/detergent solution without sodium naphthenate added and with sodium naphthenate at concentrations of 2%, 3%, and 6%.

The study included the following soiling mediums:

a. Lube Oil (30W - automotive grade)

*The linear polarization measurement is described in Corrosion Engineering by M. G. Fontana and N. D. Greene, McGraw Hill, New York, 1967, chapter 10, pg. 344.

b. Grease (90W - gear)

c. Hydraulic Fluid (MIL-H-22072A)

d. A mixture consisting of 35 gm. raw umber, 6 gm. petrolatum and 40 ml JP-5 jet fuel.

6" x 12" x ≃ .125" steel panels were soiled with the mediums listed above, washed with the different test solutions, and rinsed with sea water. The degree of surface cleanliness was then quantified by an atomizer test described in Appendix I.

C. RESULTS

1. PHASE I - IDENTIFY AND SCREEN CANDIDATE CORROSION INHIBITORS

Five sodium naphthenate solutions were synthesized and screened on their ability to reduce the corrosion rate of a metallized aluminum coupon exposed in various strength sodium metasilicate solutions. The five solutions were made up as follows:

a. Sodium Naphthenate, 47% active in Mineral Oil, viscosity = 335-350 S.U.S.

b. Sodium Naphthenate, 47% active in Butyl Carbitol

c. Sodium Naphthenate, 47.5% active in Mineral Oil, viscosity = 125-135 S.U.S.

d. Sodium Naphthenate, 40% active in Mineral Oil

e. Sodium Naphthenate diluted in water

In the first 4 solutions listed above, solvents (Mineral Oil, Butyl Carbitol) were used to dilute the naphthenic acids making it easier to prepare the sodium naphthenate. Concentrated sodium naphthenate was also prepared according to the exact procedures reported by Kyazimov[1]. This yielded a highly viscous, black substance which was then diluted with water to form an aqueous solution. The sodium naphthenate solution mixed readily with the sodium metasilicate/detergent solution.

Screening tests showed that none of the first four solutions significantly reduced corrosion of metallized aluminum in sodium metasilicate solutions. However, when an aqueous solution of sodium naphthenate was added to a sodium metasilicate solution resulting in a 3% concentration of both naphthenate and metasilicate, the corrosion rate of aluminum dropped from 20 mpy to 1 mpy. Apparently, the mineral oil and butyl carbitol solvents adversely affect the

inhibiting property of the sodium naphthenate. Because of the promising results obtained with the aqueous solution of sodium naphthenate, a more in-depth study was conducted on this formulation.

Figure 1 presents a carpet plot of corrosion rate versus different concentrations of sodium metasilicate and sodium naphthenate. Table II also presents this data. The data shows that sodium naphthenate at practical concentrations can be used to control corrosion of aluminum in caustic cleaning solutions.

Although sodium metasilicate is only used at a 3% concentration to clean the flight deck, it is suspected that the metasilicate concentrates at crevices on the flight deck through successive washing/evaporation cycles. Thus, data was obtained at 6% and 12% concentrations. Table II shows that uninhibited 12% sodium metasilicate corrodes aluminum at ≈ 100 mpy.

Figure 2 shows a plot of corrosion rate versus time for an aluminum coupon exposed in 3% metasilicate solution with and without corrosion inhibitor. The plot shows that the sodium naphthenate is stable and effective over an extended period (170 hrs.).

2. PHASE II - INVESTIGATE THE EFFECT OF SODIUM NAPHTHENATE ON THE CLEANSING ABILITY OF A 3% SODIUM METASILICATE DETERGENT SOLUTION

Tables III thru VI present the results of the cleanability tests on different soiling mediums. The results show that the addition of sodium naphthenate degrades significantly the metasilicate/detergent cleaning ability with respect to gear oil (85W-140), the raw umber/jet fuel/petrolatum mixture, and hydraulic fluid. Sodium naphthenate up to a 3% concentration did not adversely affect the ability of the metasilicate/detergent solution to clean medium grade lube oil from steel surfaces. The results presented in Tables III thru VI demonstrate the excellent reproducibility of the atomizer test for quantitatively rating surface cleanliness.

D. DISCUSSION OF RESULTS

Based on a brief literature review, the laboratory tests concentrated on one inhibitor additive - sodium naphthenate. It is possible that there are other inhibitor additives that will effectively reduce alkaline corrosion and at the same time not degrade the solution cleansing ability. A better approach rather than determining an effective inhibitor additive might be to find a substitute cleaning solution with comparable cleansing ability.

E. CONCLUSIONS

1. Sodium naphthenate at practical concentrations can inhibit corrosion of aluminum in alkaline solutions.

2. Sodium naphthenate degrades the cleansing power of metasilicate/detergent cleaning solutions.

3. Sodium naphthenate does not appear to be compatible as an inhibitor additive for metasilicate/detergent cleaning solutions.

4. Corrosion of aluminum hardware exposed on aircraft carrier flight decks will continue unless the Navy revises their current cleaning procedures.

5. A substitute cleaning solution for aircraft carrier flight decks must be found.

F. RECOMMENDATIONS

1. Initiate further work to find, test and evaluate an effective and compatible cleaning solution for aircraft carrier flight decks.

VI. REFERENCES

1. Kyazimov, A. M., Inhibitors Synthesized From Naphthenic Acids, Azerb. neft. kh-vo., No. 1, 34-8 (1968).

2. Horiguchi, K., et. al., Studies on Corrosion Inhibitor for Aluminum in Alkaline Media, J. Electrochemical Soc. Japan, V. 34, No. 3, 162-164 (1966).

TABLE I

Possible Inhibitors for Control of

Corrosion in Caustic Solutions

	Compound	Reference
1.	Sodium Naphthenate*	1
2.	Naphthenic Acid Amide*	1
3.	Naphthenic Acid Neutralized with Aniline*	1
4.	1-(2-thenoyl)3,3,3-trifluoroacetone	2
5.	Benzylacetone	2

*Prepared from Naphthenic Acid separated from Crude Oil

TABLE II

CORROSION RATE AND pH AS A FUNCTION OF % SODIUM NAPHTHENATE AND % SODIUM METASILICATE

% Sodium Metasilicate	% Sodium Naphthenate	pH	Corrosion Rate, mpy
3	0	12.9	20.03
3	1	12.9	17.7
3	2	12.2	.718
3	3	12.7	1.44
3	6	12.0	.561
3	12	12.1	.631
6	0	12.8	15.3
6	1	12.8	9.47
6	3	12.9	3.49
6	6	11.3	.706
6	12	12.6	.561
12	0	12.9	98.3
12	1	12.9	98.2
12	3	13.1	53.5
12	6	13.0	7.96
12	12	13.2	11.8

TABLE III

CLEANING INDEX FOR DIFFERENT CLEANING SOLUTIONS USED TO REMOVE RAW UMBER/JET FUEL/PETROLATUM MIXTURE

	Cleaning Solution	TEST #1	TEST #2	TEST #3
1.	Sea Water	0	0	0
2.	3% Metasilicate/Detergent	100	100	100
3.	3% Metasilicate/Detergent + 2% Sodium Naphthenate	13	10	15
4.	3% Metasilicate/Detergent + 3% Sodium Naphthenate	15	11	10
5.	3% Metasilicate/Detergent + 6% Sodium Naphthenate	0	4	2

TABLE IV

CLEANING INDEX FOR DIFFERENT CLEANING SOLUTIONS USED TO REMOVE GEAR OIL (85W-140)

	Cleaning Solution	TEST #1	TEST #2	TEST #3
1.	Sea Water	0	0	0
2.	3% Metasilicate/Detergent	100	100	100
3.	3% Metasilicate/Detergent + 2% Sodium Naphthenate	15	20	21
4.	3% Metasilicate/Detergent + 3% Sodium Naphthenate	8	20	10
5.	3% Metasilicate/Detergent + 6% Sodium Naphthenate	0	2	13

TABLE V

CLEANING INDEX FOR DIFFERENT CLEANING SOLUTIONS USED TO REMOVE LUBE OIL (30W AUTOMOTIVE GRADE)

	Cleaning Solution	TEST #1	TEST #2	TEST #3
1.	Sea Water	22	12	20
2.	3% Metasilicate/Detergent	100	100	100
3.	3% Metasilicate/Detergent + 2% Sodium Naphthenate	100	100	100
4.	3% Metasilicate/Detergent + 3% Sodium Naphthenate	100	100	100
5.	3% Metasilicate/Detergent + 6% Sodium Naphthenate	81	92	98

TABLE VI

CLEANING INDEX FOR DIFFERENT CLEANING SOLUTIONS USED TO REMOVE HYDRAULIC FLUID (MIL-H-22072A)

	Cleaning Solutions	TEST #1	TEST #2	TEST #3
1.	Sea Water	0	0	0
2.	3% Metasilicate/Detergent	78	87	72
3.	3% Metasilicate/Detergent + 2% Sodium Naphthenate	49	50	59
4.	3% Metasilicate/Detergent + 3% Sodium Naphthenate	40	46	49
5.	3% Metasilicate/Detergent + 6% Sodium Naphthenate	44	43	47

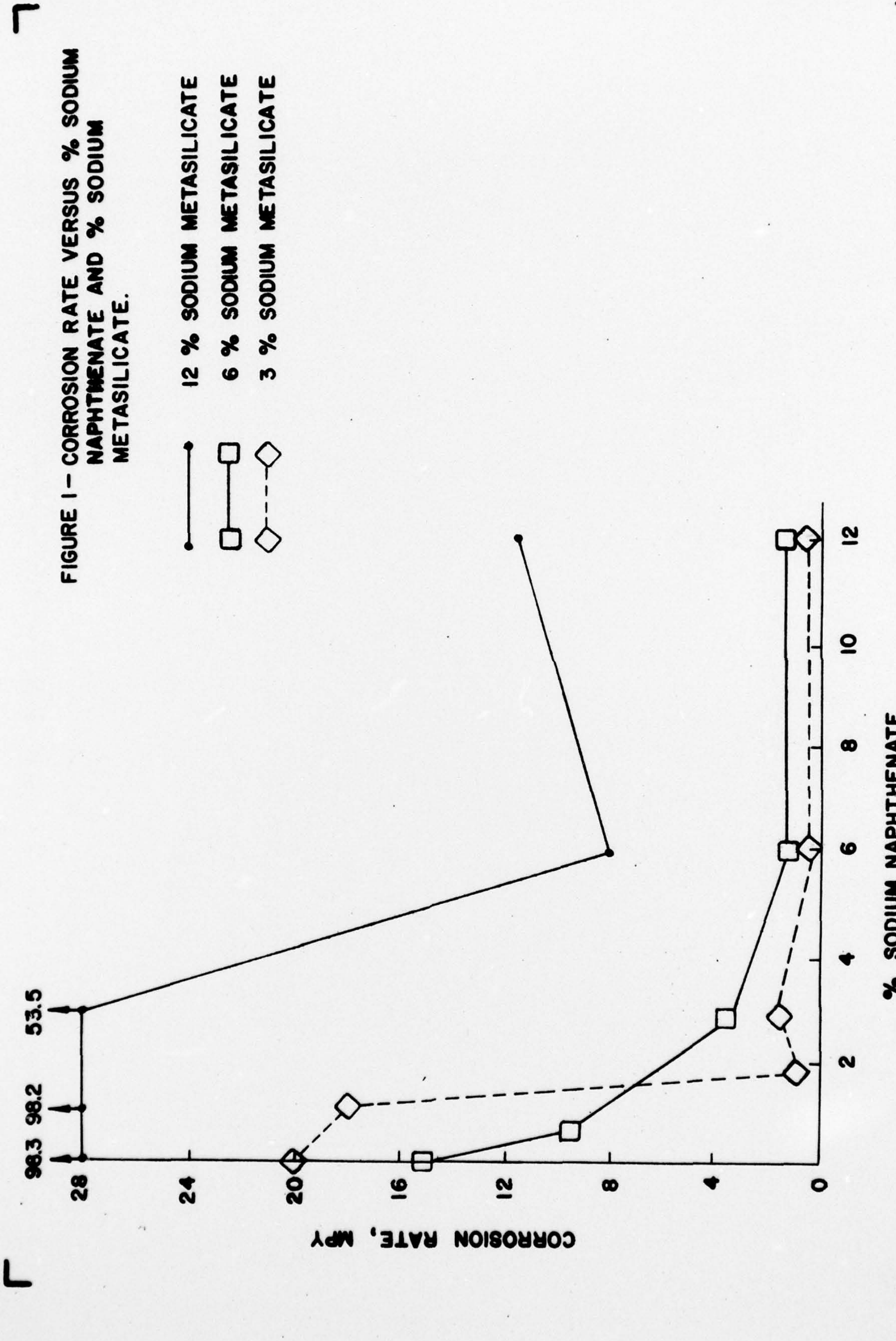

FIGURE 1 — CORROSION RATE VERSUS % SODIUM NAPHTHENATE AND % SODIUM METASILICATE.

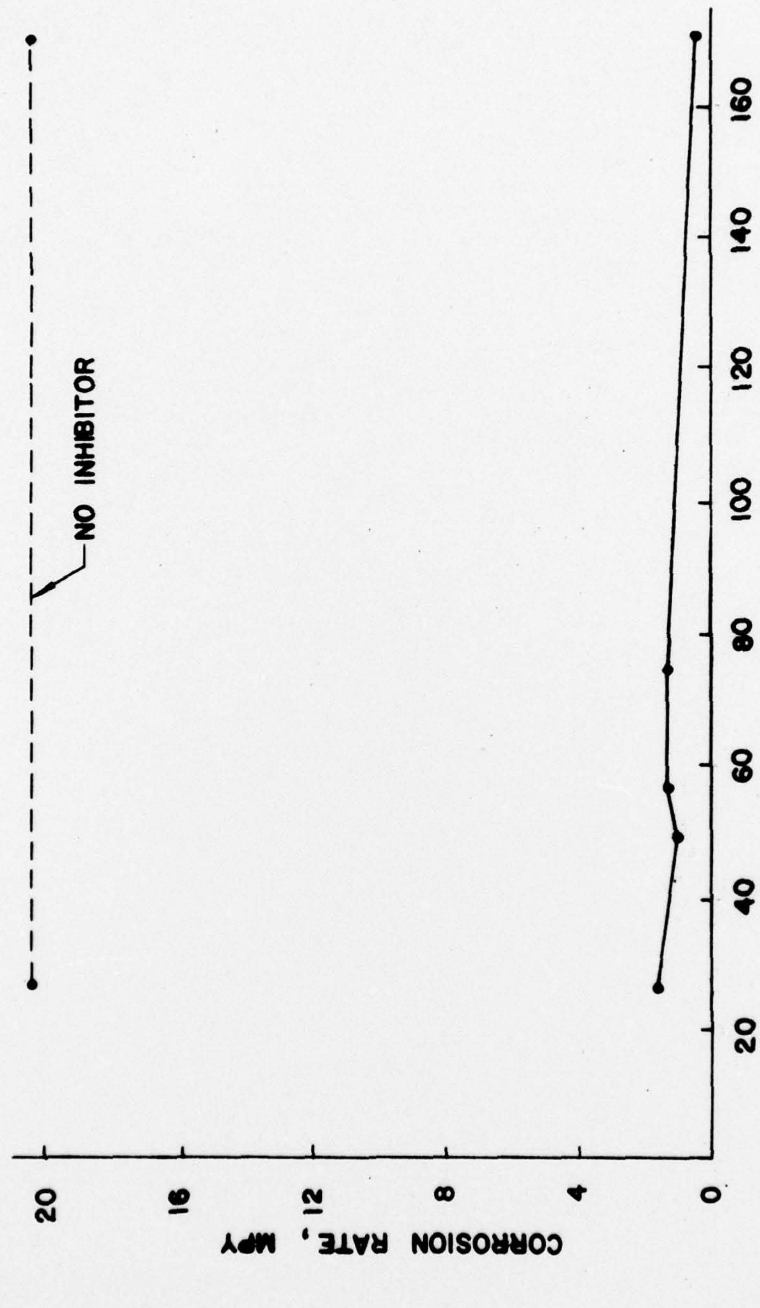

FIGURE 2– CORROSION RATE VERSUS TIME FOR ALUMINUM EXPOSED IN 3% SODIUM METASILICATE SOLUTION.

APPENDIX I

DESCRIPTION OF ATOMIZER TEST USED TO DETERMINE DEGREE OF SURFACE CLEANLINESS

Fresh water containing 0.1% blue dye was sprayed on the test panel from a distance of 2 feet at a pressure of 18 in. Hg. Total spray time was 30-45 seconds. A distinct pattern formed on the test panels depending on the degree of cleanliness. The pattern was fixed in place with a heat lamp. A cleaning index was determined by dividing the panel into 100 squares. The number of squares not covered by water was taken as the cleaning index. If none were covered, the surface was poorly cleaned and rated an index of zero. If, however, some squares were covered, then the test gave a value between zero and 100 and had quantitative significance. The dirty areas tended to form water droplets. The clean areas were covered by a continuous film formed by the coalescence of droplets. The test was run three times to increase experimental accuracy.

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